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ORIGINAL RESEARCH

vascular Coil Embolization of Aneurysms a Branch Incorporated into the Sac

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UND AND PURPOSE: Because of the concern for occlusion of the incorporated branch artery, sm with a branch incorporated into the sac has been regarded as a contraindication for e aim of this study is to evaluate the feasibility, techniques, and clinical and angiographic of coiling for aneurysms with a branch incorporated into the sac.

S AND METHODS: The medical records and radiologic studies of 69 patients with 79 aneu- ing a branch incorporated into the sac (26 ruptured, 53 unruptured) were retrospectively and evaluated.

RESULTS: Coiling was accomplished in 78 aneurysms in 68 patients but was suspended in 1 due to incorporated branch occlusion. The aneurysms were treated by using the following techniques: single-catheter (*n* = 37), multicatheter (*n* = 22), balloon-remodeling (*n* = 7), stent-assisted coiling (*n* = 6), and combined (*n* = 7). Postembolization angiography revealed the following: near-complete occlusion in 71 (89.8%), remnant neck in 4 (5.1%), and incomplete occlusion in 4 (5.1%) aneurysms. Procedure-related permanent morbidity and mortality rates were 5.8% (4/69) and 0%, respectively. All patients with unruptured aneurysms had a modified Rankin Scale (mRS) score of 0, except for 1 patient who had an mRS score of 3. Of the 26 patients with ruptured aneurysms, 18 had favorable outcome (mRS 0–2) but 8 had poor outcome (mRS 3–6). Follow-up angiography was available at least once at 6–50 months (mean, 15 months) in 55 aneurysms (69.6%), of which 45 showed stable or improved occlusion; 4, minor recurrences; and 6, major recurrences. All 6 major recurrent aneurysms were retreated without complication by using a single-catheter (*n* = 1), multicatheter (*n* = 2), or balloon-assisted technique (*n* = 3).

CONCLUSIONS: With appropriate techniques, most aneurysms with a branch incorporated into the sac could be safely treated by coiling, with acceptable outcomes.

Since its first introduction in the field of aneurysm treatment, endovascular coiling has increasingly been used with good outcome in most intracranial aneurysms. Because of the recent advances and development of various types of coils and various neck-protecting devices such as compliant balloons and neurovascular self-expanding stents, a wide-neck aneurysm is no longer a contraindication for endovascular coiling.[1,2] However, because of the concern for occlusion of the incorporated branch artery, an aneurysm with a branch incorporated into the sac has been regarded as one of the major contraindications for endovascular coiling. Recently, a small case series reported treating these aneurysms with the incorporated branch.[3] Nevertheless, to the best of our knowledge, little has been known about the feasibility, techniques, and clinical and angiographic outcomes of coiling aneurysms with an incorporated branch. In this study, we retrospectively evaluated 79 aneurysms with incorporated branches in 69 patients who underwent endovascular coiling, and we present the feasibility, techniques, and clinical and angiographic outcomes.

Received April 15, 2009; accepted after revision June 15.

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This study was supported by a grant (No. A085136) of the Korea Healthcare Technology R&D Project, Ministry for Health, Welfare & Family Affairs, Republic of Korea.

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DOI 10.3174/ajnr.A1785

Materials and Methods

The institutional review board approved this retrospective study, and patient informed consent was not required. Sixty-nine patients with 79 aneurysms having a branch incorporated into the sac, treated by coiling in a tertiary referral hospital between May 2000 and December 2008, were retrospectively evaluated. During the study period, a total of 580 saccular aneurysms in 537 patients were treated. Of those, 350 aneurysms were treated endovascularly, and the others, by clipping. The patients included 24 men and 45 women with ages ranging from 27 to 83 years (mean, 57 years). Medical records and radiologic studies were reviewed to obtain relevant information.

Endovascular Coiling

Single-regimen antiplatelet premedication (aspirin or clopidogrel) was given to all patients with unruptured aneurysms, while antiplatelet premedication was not given to the patients with ruptured ones. Anticoagulation was initiated by injection of a bolus of 3000–5000 IU of heparin intravenously at the beginning of the procedure, followed by continuous infusion of heparin at a rate of 1000 IU/h. Activated coagulation time was maintained between 2 and 3 times the baseline value during and 24–48 hours after the procedure. In most cases, coiling was initiated by using the conventional single-catheter technique with various types of coils. When the single-catheter technique failed, multicatheter (2 or 3 catheters, a catheter-supported single-catheter, or a catheter-supported 2-catheter technique), balloon-assisted, stent-assisted, or combined techniques (balloon-remodeling plus 2 catheters, stent-assisted plus 2 catheters, or a balloon-in-stent technique) were used according to the aneurysm geometry. The location of the aneurysm was also considered in the selection of the technique used. In the aneurysms that were located at a relatively small parent artery (anterior cerebral artery or middle cerebral artery), a

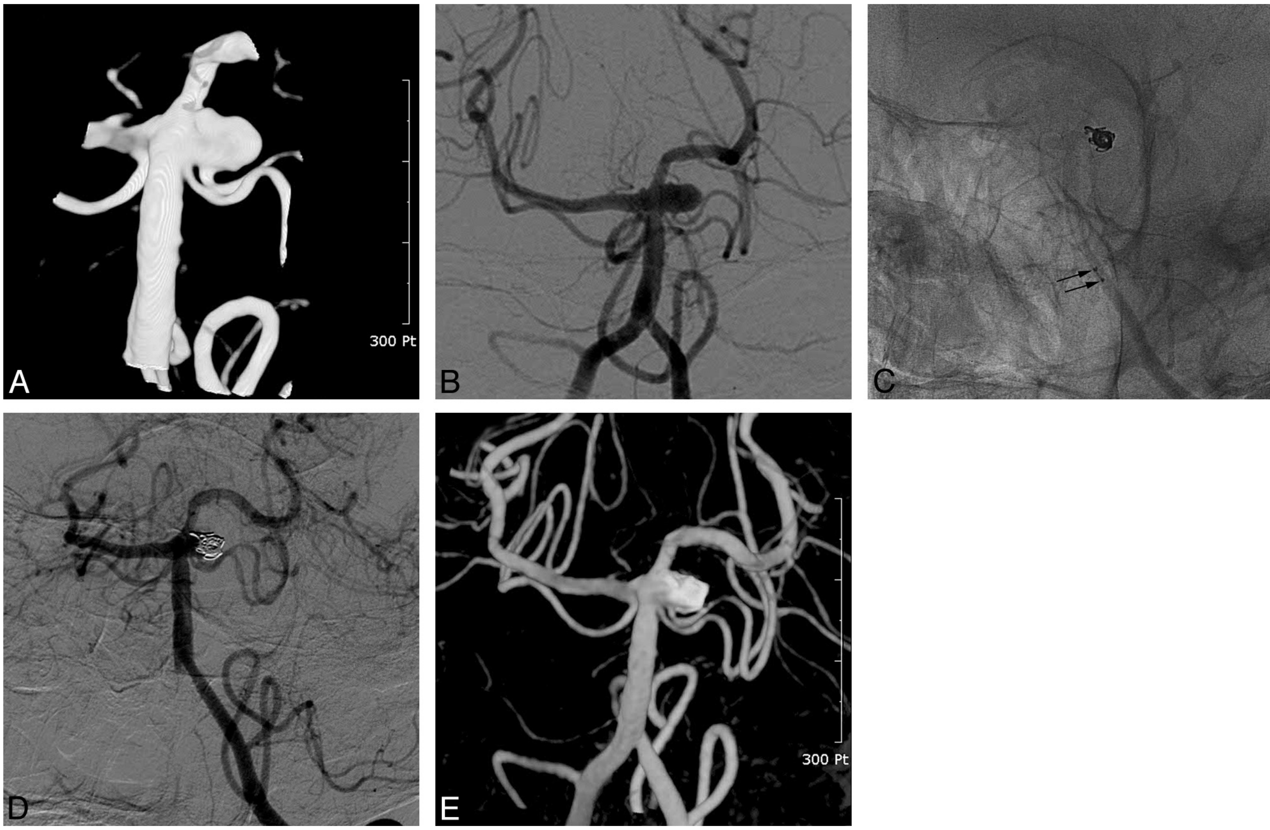

Fig 1. A 64-year-old woman with an unruptured aneurysm at the basilar artery—left superior cerebellar artery junction. *A* and *B*, 3D reconstruction image (*A*) and a working-projection image (*B*) reveal a saccular aneurysm at the basilar artery–duplicated left superior cerebellar artery origin. One of the duplicated left superior cerebellar arteries is incorporated into the sac. *C*, Coiling of the aneurysm sac is performed by using a 2-microcatheter technique. Note the radiopaque proximal markers of 2 catheters and coils (*arrows*). *D* and *E*, Postembolization control angiogram (*D*) and 3D reconstruction (*E*) image reveal near-complete occlusion of the aneurysm sac and a patent superior cerebellar artery incorporated into the sac.

multicatheter or balloon-assisted technique was preferred to a stent-assisted technique.

"Two- or 3-catheter technique" is when 2 or 3 coils are sequentially or alternatively deployed through 2 or 3 prepositioned microcatheters without detachment, making the coil basket appropriate for saving the incorporated branch (Fig 1). A "catheter-supported single- or 2-catheter technique" is used when a balloon or a stent cannot be inserted into the incorporated branch because of its small size and/or acute angulation to the parent artery. One microcatheter is inserted into the incorporated branch for protection, and the tip of the other 1 or 2 catheters is positioned into the aneurysm dome to be used for coil deployment (Fig 2). This technique is particularly useful for the aneurysms that have a small incorporated branch and a shallow dome depth.

"Combined technique" means combined use of a 2-catheter technique and a stent- or balloon-assisted technique. The parent artery is protected by using a balloon or a stent, and 2 catheters inserted into the aneurysm sac are used for making the coil basket appropriate for saving the branch incorporated into the sac. The complexity of the technique used is gradually increased to obtain a satisfactory result and save the incorporated branch. When the single-catheter technique is not effective for saving the incorporated branch, a multicatheter or balloon-remodeling technique is used. When these techniques also fail, stent-assisted or a combined technique is finally tried.

Immediate angiographic results were classified into 3 categories: "Near-complete" was defined as the entire sac of the aneurysm with the incorporated branch being occluded except for a small portion into which the branch artery was incorporated. "Neck remnant" was when contrast media filled in the neck region more than the portion into which the branch was incorporated. "Incomplete" was when contrast media filled in the aneurysm dome. Because of the nature of the aneurysm, with a branch incorporated into the sac, complete occlusion was excluded from categorization.

Clinical and Angiographic Follow-Up

The patients were clinically assessed at admission, before and after the treatment, at discharge, and at clinical follow-up by the neurosurgeons and/or the interventional neuroradiologists. Each patient's outcome was evaluated according to the modified Rankin Scale (mRS) score, and the patient's outcome at the last clinical follow-up was defined as the final outcome.

Follow-up angiographic results were classified into 3 categories: stable or improved occlusion, minor recurrence that does not require retreatment, or major recurrence that requires retreatment.

Results

Characteristics and treatment results of the aneurysms with the incorporated branch are summarized in the Table. Coiling was completed in 78 aneurysms with an incorporated branch (98.7%) in 68 patients but was suspended in 1 because of occlusion of the incorporated branch. Location of the aneurysms with the incorporated branch were the middle cerebral artery in 32 (40.5%), the internal carotid artery (ICA)–anterior choroidal artery in 21 (26.6%), the ICA–posterior communicating artery in 18 (22.8%), the anterior cerebral artery in 2 (2.5%), the ICA–ophthalmic artery in 3 (3.8%), the basilar

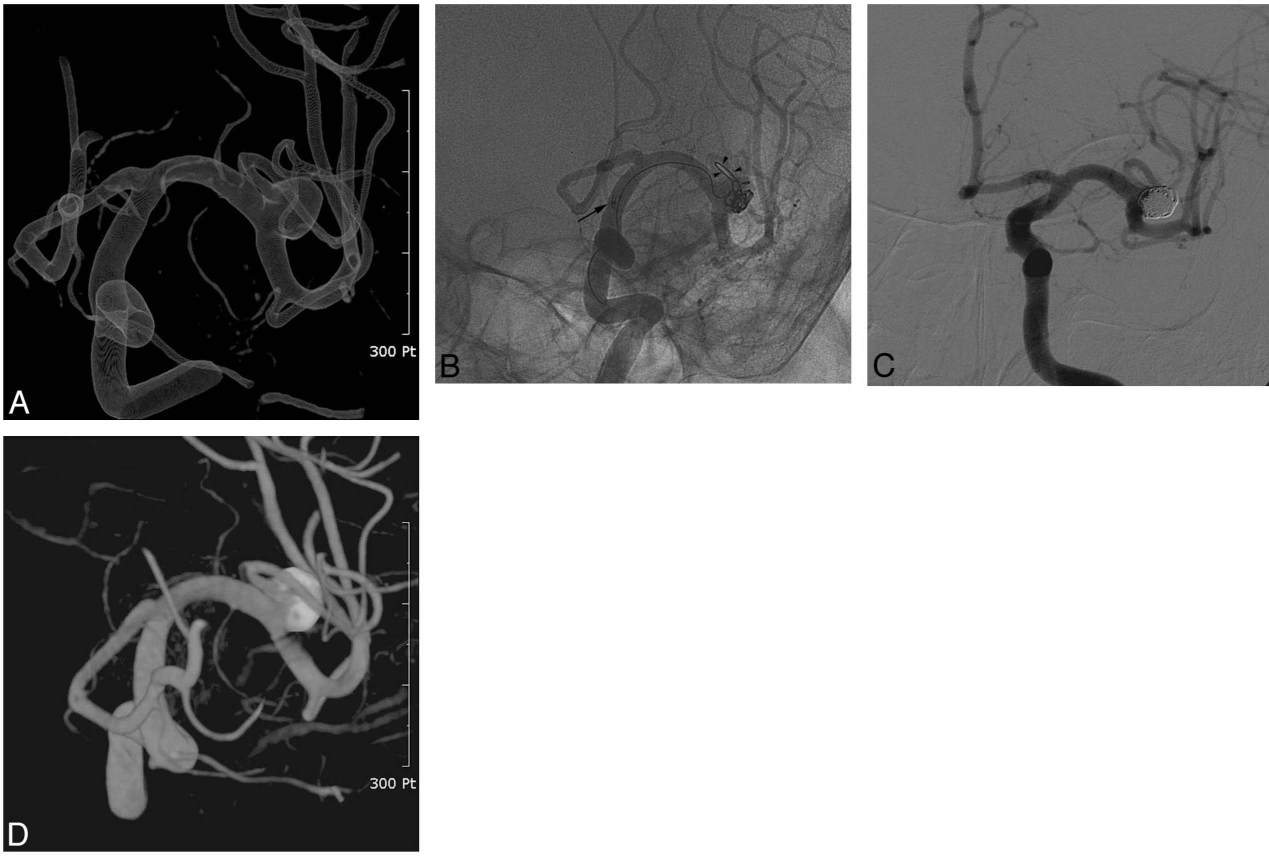

Fig 2. A 64-year-old woman with an unruptured aneurysm of the left middle cerebral artery. *A*, Transparent gradient view of a 3D reconstruction image shows a saccular aneurysm with a superior branch incorporated into the sac. *B*, Coiling of the aneurysm is performed by using a catheter-supported 2-catheter technique. The incorporated branch is selected by using a microcatheter and a coil (*arrowheads*). By gently pushing the microcatheter to support the coil mass, we performed coiling by using the other 2 microcatheters. This procedure is repeated during the coiling to preserve the incorporated branch. Note the radiopaque proximal markers of 2 catheters and coils (*arrow*). *C* and *D*, Postembolization control angiogram (*C*) and a 3D reconstruction (*D*) image show near-complete occlusion of the aneurysm sac and a patent incorporated branch.

artery–superior cerebellar artery in 2 (2.5%), and the vertebral artery–posterior inferior cerebellar artery in 1 (1.3%). Thirty-seven procedures were performed by using a single catheter; 22, by multicatheter (Figs 1 and 2); 7, by balloon-remodeling (Fig 3); 6, by stent-assisted techniques (Fig 4); and 7, by combined techniques (Fig 5). Postembolization control angiography revealed near-complete occlusion in 71 (89.8%), remnant neck in 4 (5.1%), and incomplete occlusion in 4 (5.1%) aneurysms.

Periprocedural complications occurred in 9 patients, including 7 thromboembolic events (2 cases of incorporated branch occlusion, 1 embolic infarction, and 4 transient ischemic attacks); 1 procedural aneurysm rupture, which could immediately be controlled by insertion of further coils; and 1 basal ganglia hemorrhage. Four of 7 patients with thromboembolic events and 1 patient with procedural rupture have completely recovered. Two patients with incorporated branch occlusion and 1 patient with embolic infarction developed permanent neurologic deficits (mRS 2 in 1, mRS 3 in 1, and mRS 4 in 1, respectively). A case of basal ganglia hemorrhage, which occurred 12 hours after completion of the embolization, also left a permanent neurologic deficit (mRS 3). No patient died from procedure-related complications. As a result, treatment-related permanent morbidity and mortality rates were 5.8% (4 of 69 patients) and 0%, respectively.

All patients with unruptured aneurysms had an mRS score of 0, except for 1 patient who had an mRS of 3 due to occlusion of the anterior choroidal artery incorporated into the aneurysm sac. Of the 26 patients with ruptured aneurysms, 18 had favorable outcomes (mRS 0–2) but 8 had poor outcomes, including 5 deaths. Five patients died due to the direct consequences of initial subarachnoid hemorrhage. There was no subarachnoid hemorrhage in the remaining 64 patients during the clinical follow-up periods of 3–105 months (mean, 23 months).

Fifty-five (69.6%) of the 79 aneurysms with an incorporated branch were followed-up at least once with angiography (mean, 15 months; range, 6–50 months), of which 45 showed stable or improved occlusion; 4, minor recurrence; and 6, major recurrence. All 6 major recurrent aneurysms were retreated without any complications by using a single-catheter ($n = 1$), multicatheter ($n = 2$), or balloon-assisted technique ($n = 3$).

Discussion

Since the first introduction of Guglielmi detachable coils, endovascular coiling has increasingly been used as the primary treatment technique for ruptured and unruptured intracranial aneurysms. The Intracranial Subarachnoid Aneurysm Trial (ISAT) had a pivotal role in changing the treatment strategy from clipping to coiling for ruptured intracranial aneurysms.[4] Also, in the treatment of unruptured intracranial an-

Characteristics of the aneurysms with a branch incorporated into the sac and immediate and follow-up results of coiling

Characteristic	No.
No. branch-incorporated aneurysms (patients)	79 (69)
Presentation	
Ruptured	26 (25.7%)
Unruptured	53 (74.3%)
Mean of maximum aneurysm diameter (range)	6.6 mm (2–26)
Mean of aneurysm neck (range)	4.0 mm (1.6–8.4)
Wide (≥4 mm or dome-to-neck ratio <1)	49 (62.0%)
Narrow (<4 mm and dome-to-neck ratio ≥1)	30 (38.0%)
Immediate posttreatment control angiography	
Near complete	71 (89.8%)
Neck remnant	4 (5.1%)
Incomplete occlusion	4 (5.1%)
Treatment-related complications (% of number of patients)	
Aneurysm rupture	1 (1.4%)
Basal ganglia hemorrhage	1 (1.4%)
Thromboembolic events during or after treatment	7 (10.1%)
Occlusion of the incorporated branch artery	2 (2.9%)
Embolic infarct	1
Transient ischemic attack	4
Treatment-related permanent morbidity	4 (5.8%)
Treatment-related mortality	0
Follow-up angiography (mean, 15 months; range, 6–50 months)	55 (69.6%)
Improved or stable	45 (81.8%)
Minor recurrence not requiring retreatment	4 (7.3%)
Major recurrence requiring retreatment	6 (10.9%)

eurysms, endovascular coiling has shown equal or superior results to clipping.[5-7] Owing to the recent advances and development of new devices and techniques of endovascular coiling, wide-neck aneurysms are no longer contraindications for coiling.[1,2,8-11] However, aneurysms with the incorporated branch still have been regarded as one of the major contraindications for coiling. Recently, Lubicz et al[3] reported a small series with successful treatment of the aneurysms with the incorporated branch endovascularly. However, to our knowledge, no other studies have been reported since, and still, little is known about the clinical and angiographic outcomes of coiling aneurysms with an incorporated branch. In this study, we present relatively more cases of this type of coiling.

Due to the possibility of increased risk of complication and recurrence after coiling, clipping may be superior to coiling when the patient is young and has an unruptured aneurysm with a wide neck and a branch incorporated into the sac. Nevertheless, the clinical and angiographic results of this study were more favorable than expected for coil embolization of the aneurysms with an incorporated branch. Most of the aneurysms with an incorporated branch included in this study could be treated by using various techniques except for only 1 unruptured aneurysm in which both the anterior choroidal artery and a fetal-type posterior cerebral artery were incorporated into the sac. Thromboembolic events, including 2 cases of occlusion of the incorporated branch, occurred in 7 patients, of which 3 left permanent neurologic sequelae. This thromboembolic complication rate is not higher than those of

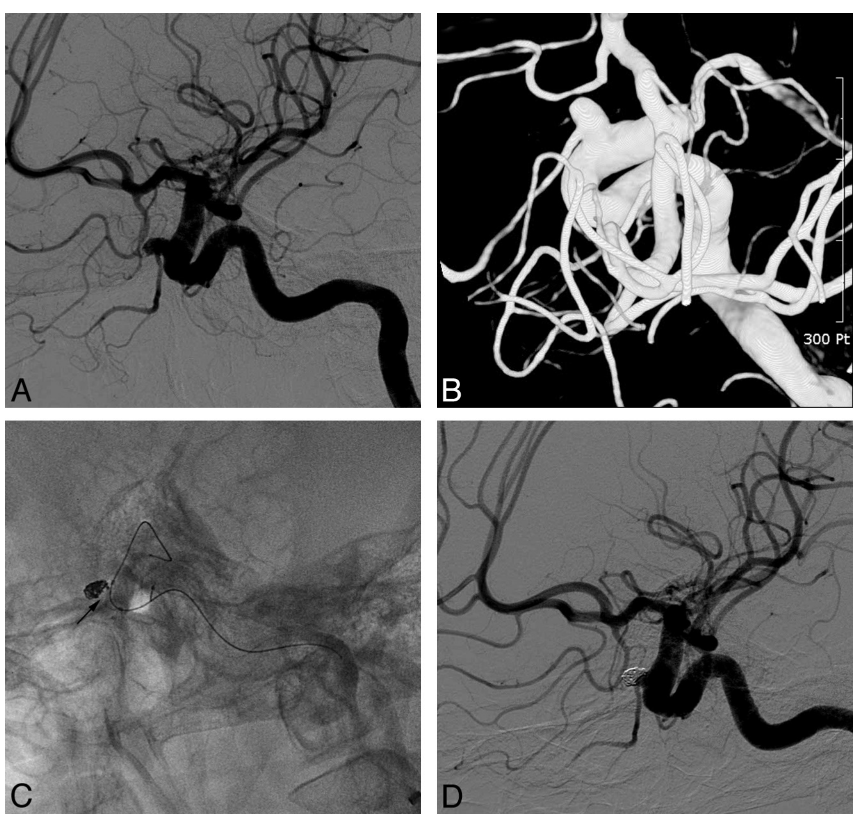

Fig 3. A 44-year-old woman with a ruptured aneurysm at the right internal carotid–ophthalmic artery. *A* and *B*, Right internal carotid angiogram in a working projection (*A*) and a 3D reconstruction (*B*) image reveal a saccular aneurysm with the right ophthalmic artery incorporated into the sac. *C*, Coiling of the aneurysm by using a balloon-remodeling technique. Coiling is performed while the HyperForm balloon is overinflated and focally herniated (arrow) into the sac to protect the origin of the ophthalmic artery. *D*, Six-month follow-up angiography reveals a stable state of near-complete occlusion of the aneurysm sac and a patent ophthalmic artery incorporated into it.

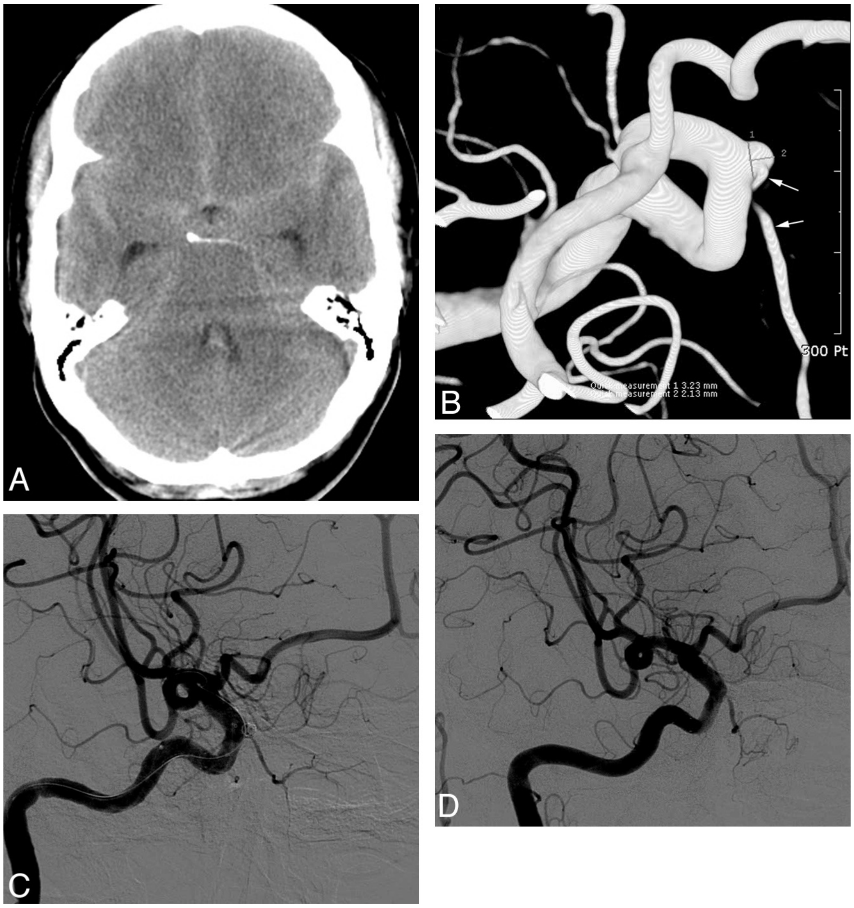

Fig 4. A 53-year-old woman presenting with subarachnoid hemorrhage. *A*, Nonenhanced CT scan shows diffuse subarachnoid hemorrhage. *B*, 3D reconstruction image reveals a small saccular aneurysm with the right ophthalmic artery (*arrows*) incorporated into the sac. Except for this aneurysm, there is no aneurysm or other vascular malformation responsible for the subarachnoid hemorrhage on follow-up angiography. *C*, Coiling of the aneurysm by using a stent-assisted technique. *D*, Six-month follow-up angiogram shows near-complete occlusion of the aneurysm sac and a patent right ophthalmic artery.

endovascular coiling for intracranial aneurysms reported in the literature.[12-14] Also, clinical and angiographic follow-up results were comparable with those of endovascular coiling reported in the literature.[15] These findings may suggest that most of the aneurysms with an incorporated branch are no longer absolutely contraindicated for endovascular coiling.

In this study, various endovascular techniques were used to complete coiling for the aneurysm with an incorporated branch. A conventional single-catheter technique was sufficient to treat 37 cases (46.8%) by using the various types of recently developed complex or 3D coils. However, the remaining 42 cases (53.2%) required various adjunctive techniques. The most commonly used adjunctive technique is the multicatheter technique. Although most of the wide-neck aneurysms could be treated by using the balloon-remodeling or the stent-assisted technique, these techniques may be limited in treating aneurysms with an incorporated branch because the balloon and stent were designed to protect the parent vessel from coil herniation, not to protect the incorporated branch.

As demonstrated by Lubicz et al,[3] the hypercompliant HyperForm balloon (ev3, Irvine, California) may be very useful in some cases of aneurysms with an incorporated branch for protection of the branch. In our experience, however, the HyperForm occlusion balloon has limitations in some cases of aneurysms with an incorporated branch because of the instability of its positioning and restriction of microcatheter control during coiling. Particularly in the cases having a low dome-to-neck ratio, the balloon-remodeling technique could not guarantee coil stability to save the incorporated branch even if the coil basket was the appropriate shape. The multicatheter technique was very useful as a primary technique or when combined with a stent or balloon in such cases. The multicatheter technique includes a 2- or 3-catheter technique and a catheter-supported single- or 2- catheter technique.[16,17] The 2- or 3-catheter technique is when 2 or 3 coils are sequentially or alternatively deployed without detachment for forming a coil basket appropriate for saving the incorporated branch (Fig 1). The catheter-supported technique, in which a catheter was used as an aneurysm-neck-protecting device for saving the parent artery, has been reported.[18]

In this study, the catheter-supported single- or 2-catheter technique was used when a balloon or a stent could not be inserted into the incorporated branch artery because of its small size and/or acute angulation to the parent artery. One catheter was inserted into the incorporated branch for protection, and the other catheter was used for coil deployment. This technique allows free control of the microcatheter, making the irregular shape of the coil basket appropriate for preserving the incorporated branch by controlling the tension of the catheter inserted into the incorporated branch, pushing the coil

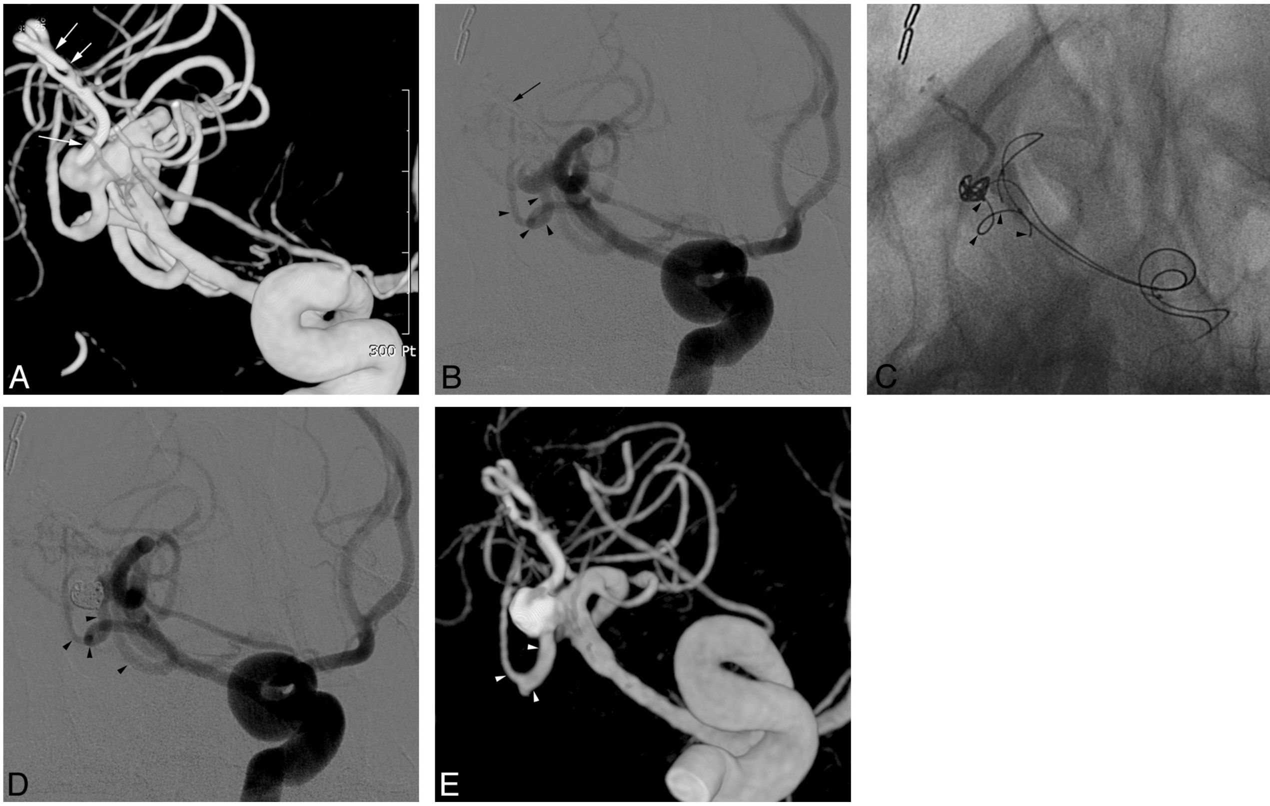

Fig 5. A 48-year-old man presenting with subarachnoid hemorrhage. *A* and *B*, One-week (not shown) and 2-week (*A* and *B*) follow-up angiograms after clipping reveal an increased size of the remnant aneurysm sac due to clip slippage. Note the slipping clip (*arrows*) and an incorporated branch artery (*arrowheads*). *C*, Coil embolization is performed by using a combined balloon- and catheter-assisted technique. Note that a microcatheter and a coil are inserted into the incorporated branch artery (*arrowheads*). *D* and *E*, Postembolization control angiogram subtraction image (*D*) and a 3D reconstruction (*E*) image show complete occlusion of the remnant aneurysm sac and preservation of the branch (*arrowheads*) incorporated into the sac.

basket away from the origin of the incorporated branch during the coil deployment (Fig 2). At times, the combined techniques (the balloon-remodeling plus multicatheter or the stent-assisted plus multicatheter technique) were very useful. In these sophisticated techniques, balloons or stents are used to protect or narrow the aneurysm neck, and 2 catheters are used to make and stabilize the coil basket for saving the incorporated branch (Fig 5). We tried these techniques sequentially for coiling, from simple to complex techniques, and could obtain satisfactory results.

The occlusion of the branch incorporated into the sac is a major concern of coiling for the aneurysm with an incorporated branch. In this study, 2 cases of the incorporated branch artery occlusion occurred permanently, both of which left neurologic sequelae (mRS 3 and 4, respectively). Moreover, although only 1 left permanent neurologic sequelae (mRS 2), 5 thromboembolic events other than the permanent occlusion of the incorporated branch, including 1 embolic infarction and 4 transient ischemic attacks, occurred in the region relevant to the incorporated branch arteries. These results, as expected, suggest that protection of the incorporated branch is one of the most important factors in determining clinical outcome.

In some cases in this series, one may ask why surgical clipping was not considered as the first treatment option. In the hospital (Kangbuk Samsung Hospital) where all cases included in this series were treated, endovascular coiling has been accepted as the first option in the treatment strategy for all unruptured aneurysms since ISAT, not only because of the relatively lower complication rate of coiling compared with clipping for treatment of unruptured aneurysms in our institution but also because of the superiority of coiling over clipping proved in ISAT. Also, in most of the ruptured aneurysms included in the present series, surgical clipping was limited because of the patient's medical condition or an anatomic factor, so endovascular coiling was used as the first treatment option.

There are some limitations in the present series. Because of the retrospective nature of this study, one of the major limitations is selection bias, which may have affected the results. However, all the unruptured aneurysms with an incorporated branch were treated by coiling without exception, and branch incorporation was not a contraindication for endovascular coiling in ruptured cases. Furthermore, all the data of aneurysms with incorporated branches treated endovascularly were recorded prospectively into a data base; therefore selection bias might have been minimized. A limited number of angiographic follow-ups is another limitation, which may have indicated a lower recurrence rate than the true one in this case series.

Conclusions

With appropriate techniques, most of aneurysms having a branch incorporated into the sac could be safely treated by coiling with acceptable clinical and angiographic outcomes.

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